ogist, the specimen in my hands will be turned over for examination to an expert.

JOHN M. CLARKE.

SHORTER ARTICLES.

PRELIMINARY RESULTS ON THE CHANGES OF ATMOSPHERIC NUCLEATION.*

1. LAST May, Mr. Harvey N. Davis, at my request, put up an apparatus in this laboratory for counting the number of nuclei in the atmosphere by measuring the coronas producible with such air under appropriate conditions. The apparatus gave promise at once, but Mr. Davis was unexpectedly called away before the observations became fruitful and the project was temporarily abandoned. Believing that an instantaneous method of at least estimating the degree of atmospheric nucleation is a desideratum,† and must throw light eventually on the origin and character of the nuclei in the atmosphere, I have recently undertaken the work myself, and the results obtained in October, after the indications of the apparatus had become warrantable, are given below.

I may add that Mr. Davis, and later Mr. R. Pierce, Jr., had been at work for some time on the measurement of the daily variation of the solar constant (a project recently set on foot by the U. S. Weather Bureau) and that I hoped from a coordination of the two classes of data to reach conclusions of interest.

2. *Apparatus.*—The original apparatus was of an improvised kind, consisting of a large, horizontally placed aspirator flask or receiver (about 10 liters in capacity, 30 cm. long and 20 cm. in diameter) in which the coronas were produced, an exhaustion reservoir and appurtenances. Atmospheric air entered by a quarter-inch lead pipe, and after passing through a coil of pipe in a water-bath, kept at room temperature as shown by a thermometer, entered the receiver and was there saturated with water. Some of the nuclei may be absorbed in this necessarily long and thin influx pipe, though the tests made did not bear this out. At all events the absorption is proportional to the nucleation and will not affect the ratios of successive nucleations in the lapse of time which are here chiefly in question. In later experiments the receiver was replaced by a cylinder 50 cm. long and 15 cm. in diameter, the walls of which, in the absence of plate glass apparatus, produced less distortion. To measure the apertures of the coronas produced in the receiver, a horizontal goniometer was placed about one meter in front of it and the small circular source of light about two meters behind, all being at the same level.

3. *Method.*—It is necessary to take in the air at some feet from the laboratory; whenever the house is colder than the atmosphere, there is a draft outward and one is apt to catch the ventilation. The influx pipe must be scrupulously without leaks for the same reason.

Since coronas actually run as far as the green centered types, considerable variation is detected and a skilled eye may often dispense with the goniometer. For this reason distortion of the coronas due to the walls of the flask is of little consequence at the outset.

In the tables the date and hour, the aperture of the corona, the character of the weather and the temperature of the influx air were taken. From these, the number of nuclei, n, per cubic centimeter was computed. The measurements showed (if s is the chord of the aperture on the given goniometer),

$$d = .002/s \qquad (1)$$

in centimeters, where d is the diameter of the fog particle. At mean atmospheric temperature (21° C.) one may put $m = 79/10^7$ grams, as the moisture precipitated per cubic centimeter of air, for the pressure difference $\delta p = 17$ centimeters of mercury, used throughout. From this the number of nuclei per cubic centimeter becomes by equation (1)

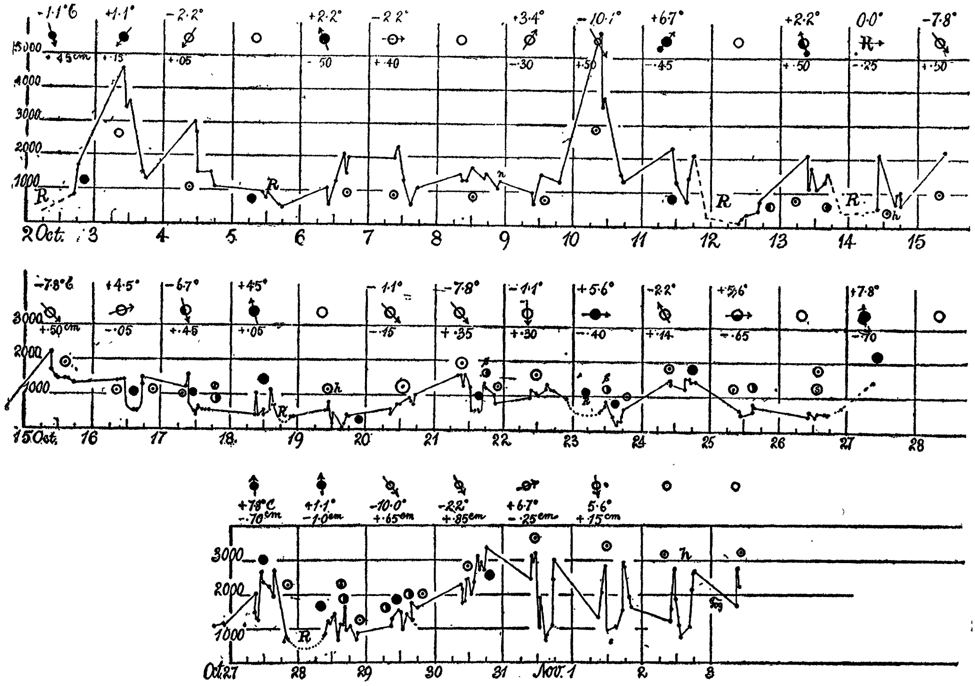
$$n = 189 \times s^3. \qquad (2)$$

4. *Errors.*—The occurrence of s^3 in (2) makes it unreasonable to expect very sharp data for n, since s is not obtainable from sharp lines. Differentiating equation (2)

* Read to the American Physical Society, October 18, 1902.

† The pioneering work of Aitken is well known. His apparatus, however, would be inconvenient for the purposes here in view.

logarithmically, an error of 1/20 in s (which need not be made) will be equivalent to an error of 34 per cent. in n. Hence the uncertainty is about 300 particles in 1,000. The variation of n is, however, somewhere between 0 and 5,000, and hence the large relative error is for the present at least without significance. The error of 300 particles is smaller, moreover, than the usual values of the minimum. Using the new long 'receiver,' s was measurable with an error less than 1/50, reducing the error of n to about 100 particles in 1,000. With properly constructed glass apparatus the conditions will be more favorable and thus fully adequate.



Finally, it should be noted for future consideration that for coronas of a high order (*i. e.*, with colored centers), the proportionality of n and s^3 is not at once assured.

5. *Preliminary Data.*—During the earlier observations made from October 2 to 14, the water-bath was not at hand. Though uncertain to this extent they are, nevertheless, very striking in their general bearing. I have, therefore, given them graphically in the chart (upper figure), where the number of nuclei is laid off vertically and the day of the month horizontally. The weather is specified as in the maps of the U. S. Weather Bureau, open circles denoting clear weather, usually with sun, black circles cloudy weather, and partially filled circles the intermediate case in which the heavens are not quite covered. *R* denotes rain. The change of temperature in degrees centigrade, during the last twelve hours, the change of the barometer in centimeters and the prevailing winds are given above the chart, for each day. Finally, *h* denotes hazy, *n* refers to observation much after sundown, etc. For convenience the observations are connected by straight lines, but where these supply the night hours they are naturally much in error.

The nucleation begins low on the second of October with the rain, but thereafter increases nearly fourfold with the bright weather of the succeeding days. Note the prevailing winds from the north. On the fifth and sixth, clouds and rain usher in a second minimum of nucleation. On the fair days

succeeding the nucleation is not as high as before until the tenth, when a sudden enormous increase occurs. The winds are here again from the north and there is marked fall of temperature. The high maximum is succeeded by an equally low minimum brought in by the rainy weather of the eleventh and twelfth. The nucleation then rises in the succeeding fair days, falls to a fourth minimum during the rain of the fourteenth, and then increases.

No doubt some fluctuation is due to variation of temperature for which no correction was made,* but the rain and fair weather effects, as a whole, are unmistakable. They here correspond to periods of minimum and maximum nucleation respectively. Moreover, the maxima are associated with winds blowing from the north in a general way, and at times with sudden fall of temperature, while the maxima of the fourth and tenth correspond to anticyclonal conditions.

6. *Data Corrected for Temperature.*—The subsequent observations were improved by aid of the water-bath, already mentioned, kept at room temperature, so that the temperature of the saturated air from which condensation takes place is fully known. The corrections are made as will be shown elsewhere. The final results are, at

10°C.	$m = 42 \times 10^{-8}$ gram.
20°	76
30°	128

From these a table may be interpolated showing the value of m for each degree of temperature between 10° and 30°, and, therefore, the number of nuclei per cubic centimeter is

$$n = 24 \times ms^3 \times 10^7$$

for the observed value of temperature and aperture, s.

In this way the following observations were corrected for temperature and the results are constructed in the graph (middle figure), beginning with October 14. Symbols referring to the weather and to other meteorological conditions are introduced as before above the graph.

7. *Remarks on the New Data.*—With the correction for temperature the curve has taken a smoother form, showing the method to be warranted; but the real cause of the differences of the two graphs is nevertheless due to actual differences of nucleation. What is particularly noteworthy is the occurrence of sharp minima on October 16, 17, 21 and 23, cotemporaneous with the passage of dense cloud masses over the sky. On the 16th, 21st and 23d the curve rises as soon as the sky clears; on the 17th this is not the case, but the curve runs into the overcast conditions of October 18. Another important feature is the remarkably pronounced minimum of nucleation on October 19, during clear weather, showing that the presence of sunshine cannot be the sole reason for an abundance of nuclei. The slight haze in the sky may not be ineffective. Similarly there is high nucleation on October 24 and 27, simultaneously with the overcast sky. A number of night observations made after October 18 show no exceptional behavior.

On October 27 the apparatus was again modified as stated, by substituting a long cylinder for the aspirator flask. Tests showed the new results to be uniformly higher * than the old, *cœt. par.*, for which reason they are separately given in the lower graph.

The data begin with high nucleation under an overcast sky and fall off to the rain storm of October 28. From this they rise again to values recalling the data of the early part of the month. The high nucleations are very fluctuating, conditions which would be even more apparent if night observations had been made. The cause is obviously convection and the diagram necessarily presents marked similarity to a wind curve.† The ascent on the 29th and the high values thereafter again

* As the air entered by a long pipe passing through the room, the temperature variations were probably within 5°C. The error so introduced is not a serious quantity, as was found by direct experiments subsequently made.

* This is due to the uneven thicknesses of the glass walls, a circumstance which need not here be considered.

† Cf. Langley, 'The Internal Work of the Wind,' 'Smithsonian Contrib.,' 1893.

correspond to winds coming in general from the north. The notched minima on the afternoons of October 31 and November 1 and 2 are curious novelties, but for them there is no other explanation than the possible haze effect as observed on the 2d.

INFERENCES.

8. *Variation.*—Mere inspection of the chart shows the extreme variability of atmospheric nucleation. Only a small part of this can be a local effect, since the changes correspond to the weather, though observation in cities where there is so much chance for pollution of the air is doubtless less satisfactory than work in the country would be. It is probable that even the small variations of the chart after October 15 are real. If the nuclei were colored the atmosphere would look like mottled soap, with the clear regions usually, but by no means always, accompanying rain or lying under clouds.

9. *Rain Effect.*—The observation next in importance is the occurrence of pronounced minima during rain, as for instance on October 2, 5, 12, 14, 19, 23, 28. There seems to be no exception to this rule. It implies a faster removal of nuclei by precipitation in a saturated atmosphere (the result of any fall of temperature) than the supply of nuclei to the same region, by either diffusion or subsidence or other more occult causes. But whether the deficiency is eventually made up from the lower air strata in contact with the lands and the seas, or from the higher air strata of the atmosphere where solar activity especially prevails, is left open.

Rain minima never fall quite down to the zero of nucleation, and are themselves quite variable in value.

One may note that the tendency of rain to change the normal air potential from positive to negative values is accompanied by a relative absence of nuclei. In other words minimum nucleation exists here cotemporaneously with maximum negative ionization.

10. *Cloud Effect.*—The third important feature, and one which became particularly evident after the temperature correction was applied (October 15), is the cloud minimum as seen on October 15, 17, 21, 23. Usually a higher nucleation is again established after the cloud train has passed over the sky, the phenomenon beginning and ending with periods of clear weather. At other times, however, the minimum remains, as on October 17.

The only explanation of this result, as will presently appear, is at hand; the air has moved bodily with the cloud, the whole constituting a region of deficient nucleation. The nuclei may have been precipitated by rain elsewhere, and the cloud may even have vanished from the region. To this extent, then, a region is identified by its nucleation.

11. *Solar Effect Absent.*—Since the nuclei cannot enter a region by diffusion as quickly as seen on October 21, for instance, one is tempted to believe that solar radiation is the cause by which the nucleation of a deficient region is reestablished. There is, however, no evidence for this in the observations, and much against it. Thus, on October 19, a remarkably low minimum is maintained almost all day in full sunlight; there were but few hazy clouds in the sky. This minimum was apparently only a part of the cloud region with which the day closed, but sunlight was powerless to replenish it. Similar reference may be made to the notched minima of November 1, 2 and 3. By contrast the high nucleation which occurs on October 25 and 27 in spite of an overcast sky may be cited. In the latter case, as on the 10th, the maximum is a precursor, as it were, of the storm which follows. Finally, though no observations were made after midnight, there are a number between sundown and ten o'clock. These show neither marked increments nor decrements, but have usually a normal character.

Hence there is no evidence, so far as these observations go, that ultra-violet light or other solar radiation has any potency in producing nucleation, and I have, therefore, explained the cloud effects, etc., as purely convective.

12. *Origin of Atmospheric Nuclei.*—Speculation as to the origin and character of these nuclei is premature. Conclusions must be

drawn with caution, since but few marked maxima have as yet been interpreted. True, the rain minima may in a general way be associated with atmospheric 'lows,' while the maxima on the 10th (and others in less marked degree) coincide with 'highs.' In so far as the cyclone and anticyclone may be regarded as upcast and downcast shafts, the supply of nuclei would seem to come from above. But as the rain minima admit of an independent explanation, and the remaining evidence is naturally vague, any such inference is precarious. Whether, therefore, the nucleation is the triturate of the land and the seas (particularly the latter), with contributions from bacteria, or whether the ultra-violet light or other radiation at the boundary of the atmosphere is the efficient source, must be left for future determination. The data already go far to show that from long series of observations of the above character much may be learned. Recalling that the coronas were obtained in ordinary glass bottles and are, therefore, distorted, the present project of studying nucleation seems secure, particularly as plate-glass apparatus will not be difficult to construct. It is, therefore, my purpose to install a small permanent plant at Brown University, and I shall take occasion to report progress if any novelty of sufficient interest makes its appearance.

Carl Barus.

THE LARAMIE CRETACEOUS OF WYOMING.

In the paper by Mr. Lambe and Professor Osborn on the mid-Cretaceous fauna of the Belly River deposits of Canada recently noticed in Science,* Professor Osborn has concluded, from the evidence presented by the vertebrate fossils, that a portion, at least, of those deposits in Montana which have previously been referred to the Laramie are really mid-Cretaceous in age, and perhaps contemporary with the Belly River series. Mr. Hatcher more recently † has called attention to the fact that a similar opinion had already been expressed by him concerning the Judith River deposits, and he is now inclined to locate them much earlier than the close of the Fox Hills time.

The Laramie deposits of Converse County, Wyoming, have usually been placed at the end of the Fox Hills, but I am somewhat skeptical of this. I believe that future research will show that, not only the Judith River beds, but also those of Wyoming will be found to be contemporary, in part at least, with the Fox Hills deposits, and that they are not separated by so great an interval from these other deposits which have hitherto been supposed to be contemporaneous.

This conclusion I base largely upon the fauna of the Wyoming beds, which present, in some respects at least, a startling resemblance to that of both the Judith River and the Belly River series.

Hitherto, almost our only published knowledge of the Wyoming Laramie fauna is that derived from Professor Marsh's writings. Aside from the Dinosaurs, he has described from these beds various lizard, snake and bird remains, but has said nothing of a number of other interesting forms of which he must have known. I can only attribute this neglect to a belief on his part that these other forms were identical with those described from the other deposits which he believed to be of equivalent age.

Among the collections made by the University of Kansas in Converse County in 1895, and those obtained by Professors Baur and Case in the same regions, there is not a little of interest in this connection. Not only a number of genera, but also a number of species previously described from Montana and now recognized by Lambe in the Belly River deposits, occur here in the supposed much later deposits of Wyoming. It would seem almost incredible that so many of these should have persisted unchanged through the long interval represented by so many thousand feet of Fox Hills deposits, to say nothing of those of the Fort Pierre. I doubt if a parallel can be found elsewhere in vertebrate paleontology. It is true that many of these forms from both the Judith River and the Laramie are known only from fragmentary remains, and that future researches may

* Science, October 24, 1902, p. 673.

† Science, November 21, 1902, p. 831.